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ABSTRACT

Reported at the National Science Teachers Association in April, 1972, in New York City, this investigation was designed to test the importance of pupil manipulation of science materials in the attainment of science process skills for kindergarten and third grade students. It has focused on a specific kind of learning task: acquisition of science process skills. Direct manipulation of materials by kindergarten children was determined to significantly increase their attainment of process skills. However, the attainment of science process skills by third grade children directly manipulating science materials was not significantly better than the attainment by children not manipulating these materials. It was concluded that the influence of direct, first-hand, manipulative experiences in the development of process skills may well be more important for the early primary grade child than for older children. (CP)

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Manipulative Experience and the Attainment of Process Skills in Elementary Science - A Research Study

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Rationale for the Study

The nature of elementary school science has changed considerably over the past several decades. Theories of instruction, the design of curricula, and views on the nature of science and science teaching have evidenced a variety of modifications. Throughout this period, however, there has remained nearly unanimous agreement that learning in young children is likely to be more efficacious if the child is involved in first-hand, direct, manipulative experiences. This concern for active pupil participation in the learning experience was advocated in the early years by writers such as Maria Montessori (1912) and John Dewey (1916), and in more recent years by the authors of the experimental science curriculum projects (Livermore, 1964; Karplus, 1963; and Hawkins, 1965). The theoretical foundation is also supportive of this notion. Developmental psychologists, such as J. Piaget (1964), J. Suchman (1960), J. Bruner (1965) and R. Gagne (1965) suggest that this active pupil participation and direct manipulation of concrete objects is important in the development of learning in elementary school age children. This experience and involvement on a non-verbal level is seen as especially important for cognitive learning in the early primary grade child.

A few experimental studies have attempted to assess the importance of pupil manipulation of materials in the attainment of certain mental skills. The results and conclusions of the various studies reveal no clear consensus of opinion. Inconsistencies in the results of these studies probably can be accounted for by differences in experimental

designs and the inability or failure to define with any certainty the level of maturity of the subjects. Moreover, the author found no studies that attempted to relate the attainment of science process skills to the extent of pupil manipulation of the science materials.

This investigation was designed to test the importance of this manipulative experience in the attainment of science process skills for kindergarten and third grade students. It has focused, then, on a specific kind of learning task (acquisition of science process skills) and has involved youngsters in two defined age categories. A study of this nature, of course, is limited in its scope and depth, nevertheless, could serve as a focus for continued research in this area.

The Hypotheses

To facilitate investigating these problems the following null hypotheses were tested:

H_o1. There was no significant difference ($p > .05$) in performance on the competency measure tasks of kindergarten children when either a maximum or minimum of pupil manipulation of materials was experienced.

H_o2. There was no significant difference ($p > .05$) in performance on the competency measure tasks of third grade children when either a maximum or minimum of pupil manipulation of materials was experienced.

Definition of Terms

The following operational definitions have been used:

1. Competency measure tasks are a series of performance tests administered to a small number of pupils at the end of each Science - A Process Approach exercise.

2. Exercise has been used in Science - A Process Approach to mean a lesson or series of lessons. Therefore, a set of learning experiences and activities.
3. Maximum pupil manipulation of materials has been used to mean that the pupil (manipulator) had a complete set of the exercise materials for his sole manipulation and that he actively used them in a manner specified for the exercise.
4. Minimum pupil manipulation of materials has been used to mean that the pupil (non-manipulator) had none of the exercise materials for manipulation. That is, he was not permitted to touch or handle any of the physical objects of the exercise; in other respects his participation was like that of the manipulator.
5. Performance indicated the correct number of responses a pupil made on the competency measure tasks. It was further used and indicated by the pupil's standard score (T-score) on the competency measure tasks. (T-Score : $\overline{X} = 50$, $s_X = 10$).
6. Process skills or processes of scientific inquiry have been enumerated as: observing, using space/time relationships, using numbers, measuring, classifying, communicating, predicting, and inferring.
7. Science - A Process Approach is one of the nationally developed elementary school science curriculum projects. The project materials were developed under the direction of the American Association for the Advancement of Science and are currently distributed by Xerox Corporation.

Experimental Procedures

Two experiments were performed to test the importance of pupil manipulation of materials in the attainment of process skills in

elementary school science. Classes of kindergarten (18 subjects; mean age 5.8) and third grade (22 subjects; mean age 8.5) students were taught and tested using the exercises and materials of Science - A Process Approach. Two treatment conditions, manipulators (T1) and non-manipulators (T2), were employed in each of the studies. Using a method of alternating subject treatment with exercise, an experimental design was constructed that placed each pupil into both of the two treatment groups.

The investigator taught four kindergarten and four third grade exercises from Parts A and D of the S-APA program over a period of fourteen weeks. During most of the instructional sessions the pupils were arranged in teaching groups of four or five each. In every group one subject was assigned to the manipulator treatment (T1) and another subject to the non-manipulator (T2) treatment condition. The rest of the subjects in each group were chosen at random from the remainder of the class. Following the teaching of each exercise, a competency measure was administered to the T1 and T2 students to assess their achievement of certain process tasks. During the teaching-testing sessions subjects T1 and T2, in each class, were matched on the basis of a pre-assessment score. Mean treatment scores on the exercise competency measures were computed and tested for significant differences using the t-test for related measures.

The dependent t is commonly used when both experimental groups have the same number of measures representing two scores on the same subjects or matched pairs of subjects (Bruning and Kintz, 1968; and Glass and Stanley, 1970). Technically the assumption of treatment scores (X) being normally distributed is necessary in using the t-statistic. However, empirical sampling studies and mathematical proofs suggest that

the test characteristics are little changed by small deviations from normality, and that quite large deviations may be tolerated as N increases (Games and Klare, 1967). Games and Klare (1967) further suggest that if the distribution of scores is generally unimodal and symmetrical, an N of 8 or 10 is satisfactory. Of course a smaller N (i.e. df) decreases the size of the critical region of rejection.

The basic experimental design and the method of tabulating the data for the experiments is summarized in Table 1.

Insert Table 1 here

Findings of the Study

The results of the competency measure testing for each experiment are presented in Tables 2 and 3.

Insert Tables 2 and 3 here

Statistical techniques were applied to test the null hypotheses.

H_o1: There was no significant difference ($p > .05$) in performance on the competency measure tasks of kindergarten children when either a maximum or minimum of pupil manipulation of materials was experienced.

The results of the testing showed that the mean score for the manipulator treatment (T1) was larger than the mean score for the non-manipulator treatment (T2). The t-test for related measures was used to determine the significance of the difference. The obtained value of the t-statistic, as presented in Table 4, was shown to be significant well above the .05 level for a two-tailed test. The null hypothesis ($\mu_{T1} - \mu_{T2} = 0$) for the kindergarten group was rejected. The manipulator

treatment led to significantly better performance on the competency measure tasks than the non-manipulator treatment.

H_o2: There was no significant difference ($p > .05$) in performance on the competency measure tasks of third grade children when either a maximum or minimum of pupil manipulation of materials was experienced.

The results of the testing showed that the mean score for the manipulator treatment (T1) was larger than the mean score for the non-manipulator treatment (T2). The obtained value of the t-statistic, as reported in Table 5, was shown to be below the .05 level of significance for a two-tailed test. The null hypothesis ($\mu_{T1} - \mu_{T2} = 0$) for the third grade group was retained. The manipulator treatment did not lead to significantly better performance on the competency measure tasks than the non-manipulator treatment.

Insert Tables 4 and 5 here

Conclusions and Implications

The data collected from the kindergarten and third grade experiments suggest three basic conclusions.

1. Kindergarten children (ages 5-6) directly manipulating science materials attain process skills better than children not manipulating these materials.

2. The attainment of science process skills by third grade children (ages 8-9) directly manipulating science materials is not significantly better than the attainment by children not manipulating these materials.

3. The influence of direct, first-hand, manipulative experiences in the development of process skills may well be more important for

the early primary grade child than for older children.

These observations are supportive of the theoretical literature that suggests that children in Piaget's "pre-operational" stage must operate on concrete objects. And that, as they mature, children become less dependent on manipulative learning and more on verbal learning. Although this may not universally be true, it seems to be supported for the learning of science process skills.

The conclusions of this study are not surprising in that they are in general agreement with popular notions on learning in children. Nevertheless, these findings convey several implications for instruction and teaching.

1. The authors of Science--A Process Approach and other process-oriented curricula encourage the teacher to involve the pupils in direct, first-hand experiences. Generally, sufficient teaching materials are provided so that each younster (or pair of youngsters) has his own set of objects. Too often, however, teachers are inclined to save time and effort by demonstrating a particular activity to the class rather than having the children perform the activity for themselves. At other times, the students are grouped in such large groups that only a few of them have a chance to handle and manipulate the materials of the science lesson. A suggestion derived from this investigation is that instruction should be handled in such a way that every pupil has an opportunity to personally engage and manipulate the materials of the lesson.

2. A second implication relates to the age and mental maturation level of the child. Generally it is assumed that direct involvement with concrete objects is more important to learning in younger children than older ones. This observation is supported by the findings pre-

sented here. However, these results should not be interpreted to mean that, without exception, a third grade child relies less on manipulative learning than a kindergarten child. In some instances an older (but less mentally mature) child may depend on manipulative learning to a greater degree than a younger (but more mentally mature) child. Since a teacher must continually account for these individual differences in learning needs among the pupils in her class, she should consider carefully any decisions to deprive any age youngster of manipulative experiences.

3. Although the results of this study relate to the importance of manipulation in the learning of process skills, there are no reasons to believe that they do not have implications for learning other skills in other subject areas.

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Table I Summary of the Basic Experimental Design

IG	Ss	Tp	01	02	03	04	TI	T2
I	1	70*	TI	T2				
	2	68	T2	TI				
	3	66			T2	TI		
	4	64			TI	T2		
II	5	63	T2	TI				
	6	61	TI	T2				
	7	60			TI	T2		
	8	59			T2	TI		
III	9	59	TI	T2				
	10	55	T2	TI				
	11	54			TI	T2		
	12	50			T2	TI		
IV	13	45	TI	T2				
	14	42	T2	TI				
	15	40			T2	TI		
	16	39			TI	T2		
V	17	37	T2	TI				
	18	35	TI	T2				
	19	32			TI	T2		
	20	29			T2	TI		

IG Interval Group
Ss Subject Rank
Tp Pre-assessment T-score
TI Manipulator T-score
T2 Non-manipulator T-score
$\bar{X}$ Treatment Mean
s_X Treatment Standard Deviation
01, 02, 03, 04 Exercise Identity

* Hypothetical Scores and Exercise Identities

Table 2 Results of the Competency Measures for the Kindergarten Experiment

IG	Ss	Tp	c	d	k	o	TI	T2
I	1	73	54	57			54	57
	2	64	61	57			57	61
	3	55			39	55	55	39
	4	54			57	49	57	49
II	5	54	39	57			57	39
	6	54	61	57			61	57
	7	53			57	31	57	31
	8	53			39	55	55	39
III	9	50	39	57			57	39
	10	47	54	37			54	37
	11	47			57	43	57	43
	12	47			57	61	61	57
IV	13	46	61	37			61	37
	14	45	54	47			47	54
	15	42			57	61	61	57
	16	39			39	43	39	43
V	17	43	39	37			39	37
	18	33	34	57			57	34
$\bar{X}$							54.8	45.0
s_X							6.6	9.6

IG Interval Group
Ss Subject Rank
Tp Pre-assessment T-score
TI Manipulator T-score
T2 Non-manipulator T-score
$\bar{X}$ Treatment Mean
s_X Treatment Standard Deviation
c, d, k, o Exercise Identity

Table 3 Results of the Competency Measures for the Third Grade Experiment

IG	Ss	Tp	k	t	u	v	TI	T2
I	1	76	70	70			70	70
	2	75	55	41			41	55
	3	71			66	66	66	66
	4	69			45	46	45	46
II	5	65	55	55			55	55
	6	59	48	41			48	41
	7	56			53	56	53	56
	8	54			45	46	46	45
III	9	54	48	41			48	41
	10	54	55	70			70	55
	11	52			66	66	66	66
	12	48			38	46	46	38
IV	13	46	40	41			41	40
	14	46	48	41			48	41
	15	44			66	56	56	66
	16	37			53	36	53	36
V	17	37	40	41			40	41
	18	31	40	41			41	40
	19	29			30	46	46	30
	20	29			53	36	53	36
VI	21	25	32	55			55	32
	22	20	48	70			48	70
	$\bar{X}$						51.6	48.4
	s_X						9.2	12.8

IG Interval Group
Ss Subject Rank
Tp Pre-assessment T-score
TI Manipulator T-score
T2 Non-manipulator T-score
$\bar{X}$ Treatment Mean
s_X Treatment Standard Deviations
k, t, u, v Exercise Identity

Table 4 Results of the Dependent t-test for the Kindergarten Experiment

Critical Regions:	Hypotheses:	
$R = \lvert t_{.05} \rvert = 2.110$		
$R = \lvert t_{.01} \rvert = 2.898$	Ho: $\mu_{T1} - \mu_{T2} = 0$	N = 18
$R = \lvert t_{.001} \rvert = 3.965$	Ha: $\mu_{T1} - \mu_{T2} \neq 0$	df = 17

Manipulator (T1) Treatment Mean	= 54.8	$t_o = 3.92$
Non-manipulator (T2) Treatment Mean	= 45.0	

Macbeth

Table 5 Results of the Dependent t-test for the Third Grade Experiment

Critical Regions:	Hypotheses:	
$R = \lvert t_{.50} \rvert = 0.686$	Ho: $\mu_{T1} - \mu_{T2} = 0$	N = 22
$R = \lvert t_{.10} \rvert = 1.721$	Ha: $\mu_{T1} - \mu_{T2} = 0$	df = 21
$R = \lvert t_{.05} \rvert = 2.080$		

Manipulator (T1) Treatment Mean = 51.6

Non-manipulator (T2) Treatment Mean = 48.4

$t_o = +1.41$